Current status and future prospects of Smart Agriculture

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1. Introduction

Agriculture around the world faces many common issues, such as reduced availability of arable land due to climate change and soil degradation, and reductions in the number of farm workers, especially skilled workers. Besides improving productivity, there is also a need for sustainable food production that is safe, secure, and has a low environmental impact. As a way of addressing these issues, precision farming (PF) has been actively studied in the West since the 1990s. For example, it is becoming essential for producers to improve their profits by making use of technologies such as auto-steering devices that use global navigation satellite systems (GNSS), yield maps produced by combine harvesters with yield monitoring functions, and satellite imaging for soil analysis and crop yield prediction.

Farming in Japan faces similar issues, and at Kubota we are developing next-generation farming technologies to resolve them, including Smart Agriculture technology based on ICT and IoT (autonomous and unmanned farm machinery for data-driven Japanese-style precision farming and super labor savings). In this way, our aim is not only to sell and service agricultural machinery, but also to provide total solutions that benefit the entire value chain.

This paper describes the current status and future vision of Smart Agriculture at Kubota, and discusses the possibility of using big data analysis and AI in order to achieve further advances.

2. The significance of Kubota's work on Smart Agriculture

(1) Current situation and issues of Japanese agriculture

Japanese agriculture currently faces many challenges and has reached a major turning point. For example, between 2000 and 2015, the number of commercial farms in Japan almost halved, falling from 2.3 million to 1.3 million. The average Japanese farmer is now over 67 years of age, and it is predicted that the number of farmers will decrease by half over the next decade.

On the other hand, there are a growing number of farming groups and people whose main business is agriculture (i.e., professional farmers), and their farms have increased in scale by assimilating smaller lots that belonged to people who have left farming. The government has taken various steps to increase the proportion of farmland owned by professional farmers from its current level of 56% to 80% by 2023. Since 2018, the long-standing policy of reducing acreage for rice cultivation has also been abolished, forcing Japanese farmers to finally become independent.

In this situation, we have to tackle the following challenges to ensure the sustainable development of Japanese agriculture:

(a) Japanese agriculture should stand independently as an attractive business.

(b) The agricultural working environment should be reformed to release farmers from heavy work and encourage young people to enter the business.

(c) Rural areas, including mountainous regions, should be revitalized and should develop and maintain multifunctional roles of agriculture.

(2) The challenges faced by professional farmers, and Kubota's efforts

Increasing the scale of farming operations presents many challenges to professional farmers and farming corporations who support Japanese agriculture, as outlined below.

[Challenges faced by professional farmers]

(a) Problems in managing multiple farm lots
  (i) Lowering of yield and quality
  (ii) Management of an increasing number of workers
(b) Labor savings and workload reductions, reduction of production costs
(c) Offering products with higher added value (branding)
(d) Human resource development (transferring know-how)
(e) Development and expansion of sales channels

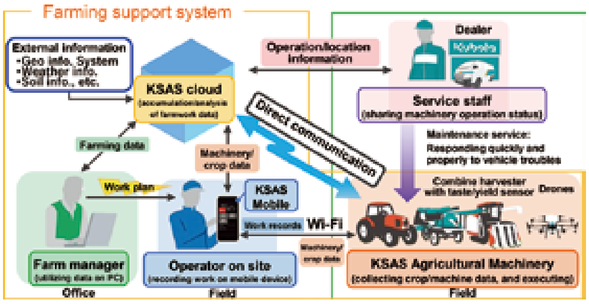
To make Japanese agriculture more attractive and profitable, it will also be necessary to visualize the entire agricultural system and build mechanisms within the food value chain whereby farmers only produce products that are required by the market at the time of need and in the desired quantities (i.e., minimizing waste). To achieve this, it is essential to develop and popularize smart agriculture systems based on ICT and IoT technology.

3. Using data for precision farming

(1) Kubota Smart Agri System (KSAS)

KSAS is a new support system for farm management and services that was developed by Kubota. It allows farmers to implement a profitable PDCA management style by using agricultural machinery and ICT to gather and utilize information about work activity and crop data (yield and taste). As shown in Figure 1, the overall structure of this system comprises KSAS agricultural machinery equipped with wireless LAN hardware and direct communication units, KSAS Mobile equipment that workers can use to record their work and relay other information, and a KSAS cloud server system that stores and analyzes

■ **Figure 1: The overall picture of the current KSAS**



information.

A farming support system and machinery service system operate on top of these components with the aim of providing value in the following ways:

[Farming support system]

(a) Producing tasty rice with high yields

(b) Producing crops in a safe and secure manner (ensuring traceability)

(c) Allowing farmers to work more efficiency and transfer their cultivation know-how

(d) Providing stronger foundations for farm management (cost analysis and reduction)

[Machinery service system]

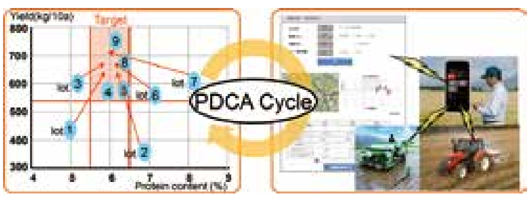
• Reducing downtime during the busy season by providing quick and appropriate services based on the location, operation and error information provided by agricultural machinery

[PDCA agriculture based on data]

The combine harvester, which plays one of the most important roles in the current KSAS system, is equipped with a load cell and a near-infrared spectroscopic analysis sensor that perform real-time measurements of not only the weight of rice in the grain tank, but also its protein content and moisture content, which are the main substitutional characteristics for the taste of rice. Every time a rice field is harvested, this measurement data is transmitted to a cloud server together with the combine harvester's operating data. Hitherto this transmission was performed via a KSAS mobile device, but since 2019 it has been performed by direct communication.

With this system, the farmer can use a PC in the office to see at a glance the data stored on the cloud server, including work records and the dispersion of yield/flavor in each individual lot (left side of Figure 2). By combining this information with the results of soil analysis, it will be possible to implement soil improvement measures tailored to the characteristics of each lot, and to create fertilizing plans for the following year. This planned fertilizer application data can be transmitted to KSAS rice transplanters and tractors via their operators' mobile phones. On receiving this information, KSAS agricultural machinery can automatically meter the dosage of fertilizer, so even a novice operator can easily fertilize over a hundred rice fields.

■ **Figure 2: PDCA cycle by KSAS**



In this way, by repeatedly iterating through a cycle where data gathering leads to work planning, followed by cultivation/harvesting, and then by more data gathering, it is possible to make continuous improvements to both the yield and taste of crops by optimizing the use of fertilizer and the allocation of human effort. This corresponds to a PDCA approach to agriculture based on the use of data that has not previously been applied to Japanese agriculture (Figure 2).

During a three-year trial in Niigata prefecture and other parts of Japan, this approach was found to boost yields by 15% and deliver an end product with a better and more stable taste. Furthermore, farmers were able to sell premium quality rice at a higher price due to its superior taste, and were able to stabilize the quality of their product and sort it according to its moisture content to reduce the drying costs.

This KSAS system is highly rated by users, who have reported achieving greater field management efficiency and better rice quality and yield. Over the roughly five-year period since the service began in June 2014, approximately 1,860 farming systems have been set up at over 8,000 subscribers (including service systems) with a total registered area of 78,000 ha (average 42 ha) covering 357,000 lots (average 190 lots).

(2) Future developments in KSAS (possible use of AI)

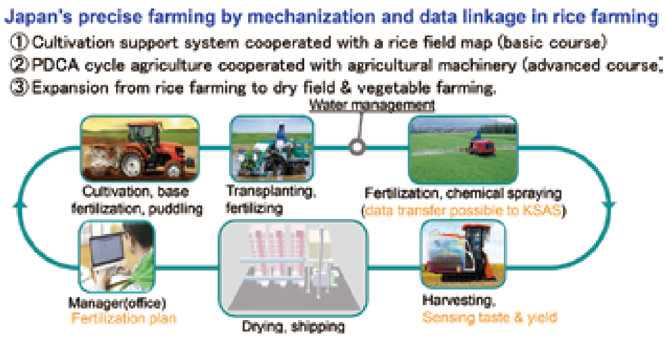
Step 1 (Figure 3) is to realize PDCA type agriculture by establishing data links with every item of agricultural machinery in an integrated rice farming mechanization system. We will also promote research and development aimed at the implementation of Steps 2 and 3.

As farmland consolidation has been promoted by the government, resulting in lots that are larger in area, it is becoming increasingly important to manage dispersion within an individual lot. Therefore, for Step 2 we are working on enabling more precise cultivation by developing agricultural machinery systems that enable sensing of soil and growing environments, growth conditions, and yield dispersion in the field and enable more precise cultivation as listed below (see Figure 4).

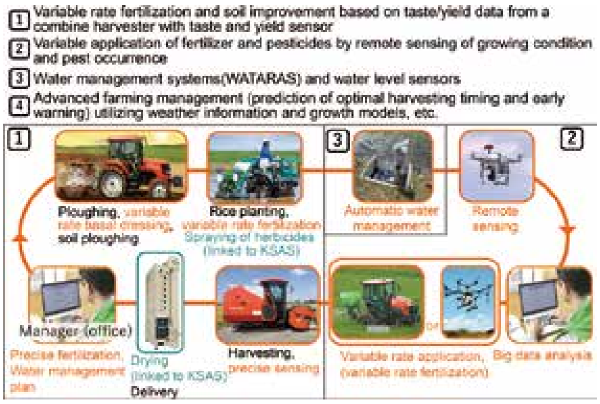
1 Combine harvesters with precise taste/yield sensors became commercially available with the launch of Kubota's WRH1200 general purpose combine harvester in April 2018, and since January 2019, we have been selling the DR series of head-feeding combine harvesters.

2 Remote sensing is undergoing monitoring tests throughout Japan in 2019.

■ **Figure 3: KSAS Step 1(in service)**



■ Figure 4: KSAS Step 2



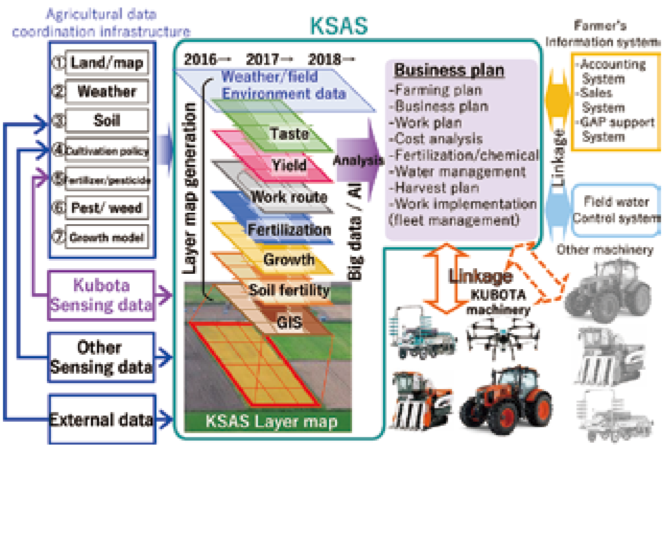
3 WATARAS, our farm water management system, was released in 2018. In the future, we plan to link this system with KSAS.

4 We plan to establish links with the WAGRI agricultural data collaboration platform.

As part of these efforts, it may be possible to use AI in fertilization design, which is currently performed based on diverse sensing data and customer experience. For example, AI could suggest how much fertilizer to use based on taste/yield data obtained by a taste/yield-sensing combine harvester, or it could judge the crop's stage of growth based on remote sensing images or the like and adjust the amount and timing of topdressing accordingly. By adding other information such as weather forecasts, this technology could even be applied to AI-based automation of water management and prediction of optimal harvest times.

For Step 3, with the aim of building an advanced farming support system, in addition to the functions of Step 2, by using AI to analyze and process big data obtained by collaborating with information systems used by farmers (such as accounting and sales systems) and external data (such as market information and information from distribution networks), we plan to push forward the evolution of advanced farming simulator technology that can support business planning and cropping using the most suitable crops in order to maximize the profits of arable farmers. In addition, we hope to be able to support the creation of optimal work plans detailing where, when and by whom which item of machinery should be operated in order to maximize efficiency. (Figure 5)

■ Figure 5: KUBOTA'S future plan of Smart agriculture and KSAS Layer map



By making KSAS as useful as possible for farmers, we hope to increase the number of farmers that use this system. To this end, it is essential to utilize and collaborate on public and private data such as farmland data & maps, weather information, soil analysis results and growth models, and it is also important to collaborate with other agricultural machinery and information systems. For this reason, we are participating in the Agricultural Data Collaboration Platform Council (WAGRI) and are working on the implementation of a common infrastructure for agricultural data. Through the work being carried out at WAGRI, we hope to be able to make use of the findings of research organizations such as the National Agriculture and Food Research Organization (including the use of AI to predict pest infestations).

4. Automation for super labor savings

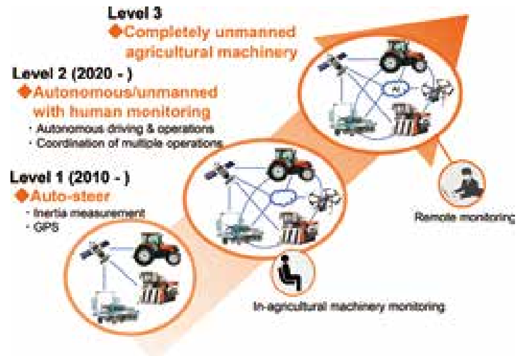
(1) Automatic/unmanned agricultural machinery

In addition to KSAS, which uses data to improve the efficiency of cultivation process management and farm management, we are also researching and developing autonomous and unmanned agricultural machinery based on robot technology with the aim of achieving further increases in the efficiency of work such as tilling and reaping that has already been mechanized, so that precise work can be performed with super labor savings. The Ministry of Agriculture, Forestry and Fisheries defines three levels of automated and unmanned technology (Figure 6), and Kubota is also working on the following themes:

Level I auto-steer technology uses the Global Navigation Satellite System (GNSS) to perform automatic steering. Kubota was the first Japanese manufacturer to offer large-scale commercial tractors (130–170 hp) for upland farming with auto-steering functionality (RTK-GNSS), starting with the M7 series released in the spring of 2015.

Since the fall of 2016, we have also launched rice transplanters equipped with go-straight functions. Existing auto-steering equipment was bulky and expensive, but by developing our own control mechanism combining an inexpensive sub-meter GPS (D-GPS) and an IMU (inertial measurement unit), we were able to implement a compact, low-cost auto-steering system. As a result, even a novice operator can plant rice seedlings with the same precision as a veteran, making the task much less stressful. This system has not only received high acclaim from purchasers, but has also received a Nikkei Excellent Product and Service

■ Figure 6: Autmation level of agricultural machinery



■ **Figure 7: Autonomous agricultural machinery**

Award and a Japan Top Ten Product Award. We are currently developing this function so that it can also be used in small and medium tractors. Furthermore, in December 2018, we launched a combine harvester with an automatic driving assist function (WRH1200A).

Level II corresponds to autonomous or unmanned machinery under manned monitoring, and includes cooperative work involving unmanned and manned machinery. Demonstration tests have shown that this level of autonomous and unmanned operation improves on the efficiency of conventional operations by around 1.5 times. Kubota has pioneered developments in this field, and in the fall of 2017, we started test marketing of a level II autonomous tractor (the SL60A Agri Robo Tractor; Figure 7, center). By using a high-precision GNSS system called RTK-GNSS, which we manufacture ourselves, this made it possible to perform automatic driving with a single unmanned tractor, cooperative driving with a pair of manned and unmanned tractors working together, and automatic steering of a manned tractor. As safety features, this tractor has a laser scanner and ultrasonic sonar to stop reliably when it detects humans and obstacles, and a system that constantly monitors the surroundings with four cameras. As a result, it complies with the autonomous agricultural machinery safety guidelines prescribed by the Ministry of Agriculture, Forestry and Fisheries.

(2) Future plans for the evolution of autonomous and unmanned agricultural machinery

With regard to the evolution of autonomous and unmanned agricultural machinery, we first aim to complete Level II. In addition to the tractors that have already been launched, we are also developing autonomous combine harvesters and rice transplanters, and we are making further advances in farm automation, including the autonomous operation of work at field boundaries, and expansion of the range of applicable implements by enhancing the control systems. When doing so, safety awareness is essential. We believe that the use of AI will be the key to identifying humans and animals in crops, detecting obstacles in the dark, recognizing boundaries, and so on.

At the same time, we are preparing to provide compatibility with the quasi-zenith satellite system promoted by the Japanese government. We expect it to become more widely used if it is possible to reduce the cost of receivers and achieve 5–6 cm accuracy without requiring a base station.

Next, Level III corresponds to completely unmanned machinery with remote monitoring, where the aim is to perform unmanned work in multiple fields, including driving on farm roads. To achieve this, it will be necessary to make further developments in farmland infrastructure, including farm roads and safety systems, and to install high-speed communication infrastructure (such as 5G) to increase the speed of monitoring and control. If tractors are completely unmanned, then they must be capable of driving on roads with their implements attached. This requirement raises issues besides technological developments, such as relaxation of the Road Traffic Law. Thus, achieving Level III requires not only research and development, but also the creation of standards and infrastructure in cooperation with the government and industry organizations.

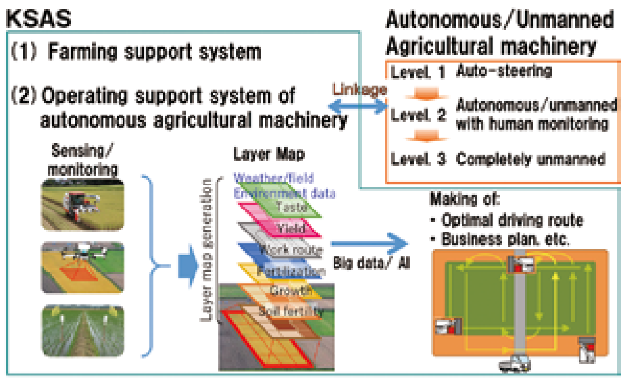
In single operations, autonomous and unmanned agricultural machinery are of limited effect. For this reason, Kubota has constructed an operating support system for autonomous agricultural machinery. As shown in Figure 8, this system is linked to KSAS to enable the optimal operation and management of multiple agricultural machinery, including those that are not fully autonomous. We are also working on the construction of a mechanism that supports the planning of optimal driving routes for multiple machinery, and can collect, monitor and use information from autonomous machinery.

5. Conclusion

As shown in Figure 9, our purpose in developing the smart agriculture discussed in this article is to establish an integrated smart agriculture system covering every aspect of farming in rice and other crops, open-field culture and fruit growing. In this way, we hope to continue addressing the challenges faced by farmers in Japan. We also hope to make a contribution to solving global agricultural challenges by developing KSAS primarily for rice farming and large-scale upland farming in Asia.

References
- 2015 Agriculture and Forestry Census (Ministry of Agriculture, Forestry and Fisheries), 2016/2017
- Smart agriculture research group web page (http://www.maff.go.jp/j/kanbo/kihyo03/gityo/g_smart_nougyo/)
- Agricultural Data Collaboration Platform Council (WAGRI) web page (https://wagri.net/)

■ **Figure 8: Cooperation between KSAS and Autonomous agricultural machinery**



■ **Figure 9: KUBOTA's aim and value of Smart agriculture**